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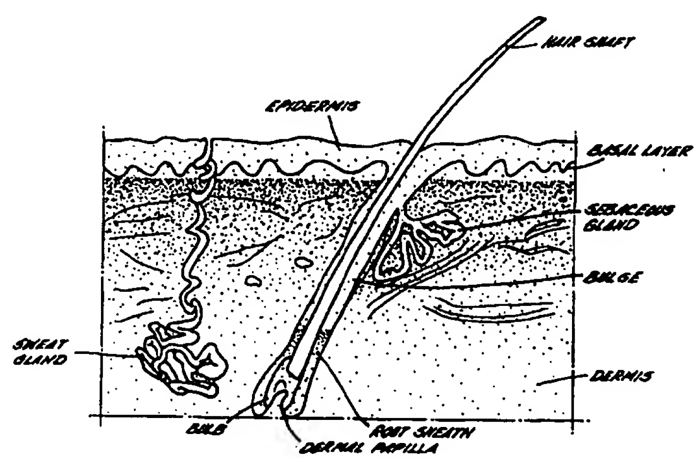

(57) Abstract

There is described an apparatus for the depilation of mammalian tissue (5) comprising a source of laser radiation (1) adapted to irradiate a target area (6) with continuous wave or quasi continuous wave laser radiation (7) having a wavelength in the range from 600 nm to 1100 nm and an energy density in the target area of between 2 J/cm^2 and 25 J/cm^2 for a duration of between 200 μs and 5000 μs so as to thereby selectively fatally damage the sub-dermal biological material associated with hair growth. There is also described a method for the depilation of mammalian tissue (5) comprising the steps of providing a source of laser radiation (1) directing the laser radiation (7) at a target area (6), and illuminating the target area (6) with continuous wave or quasi continuous wave laser radiation having a wavelength in the range from 600 nm to 1100 nm and an energy density in the target area of between 2 J/cm^2 and 25 J/cm^2 for a duration of between 200 μs and 5000 μs so as to thereby selectively fatally damage the sub-dermal biological material associated with hair growth.

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LASER DEPILATION APPARATUS AND METHOD

The present invention relates both to a depilation apparatus and to method of depilation.

Depilation (the removal of body hair) is often necessary for medical reasons, however a large percentage of the population, both male and female, require depilation for cosmetic purposes. The medical requirement may be due to the need for a skin graft from one area supporting hair growth to another where hair growth is not wanted. Medical applications however create a very limited market and hence a small commercial opportunity. By contrast it is estimated that 30% of the population of the developed world require cosmetic depilation at some time or other. If a technique could be developed to offer successful depilation for an extended period then a very major commercial opportunity would emerge.

There are several depilation techniques already available to the individual for personal use or which may be applied by others on visiting a clinic operated by trained personnel. These include:

Shaving:	the removal of hair at the surface of the skin by a sharp blade;
Plucking:	the extraction of hair either individually by the use of tweezers, or in bulk using a variety of purpose built machines;
Waxing:	the extraction of hair using a wax which upon application is in a fluid state. On solidifying, the wax grips the hair and when ripped from the surface, the wax brings the hairs with it;

Electrolysis: the destruction of individual hair follicles by the application of electrical current.

These techniques have many limitations and evidence shows that they offer control of hair growth for, at most, 10 to 12 days. Nevertheless, they represent a major business sector which could be dramatically expanded if the period of depilation could be significantly extended.

The major drawback of these techniques is that after treatment the origin of the hair is left intact and so, after a certain period of time, the hair grows back. Procedures such as shaving are only satisfactory for a short period measured in days, while more painful and expensive methods like waxing can last one or two weeks, but ultimately with the same result - the hair grows back. Electrolysis, the only "permanent mode" of hair removal currently available commercially, is not a practical method for large areas as in a single session the number of hairs that can be removed realistically is limited to around a hundred. Furthermore, with this technique there is also a tendency to damage the surrounding tissue leading to the possibility of scarring. It would therefore be desirable to provide a new technique capable of permanently removing hair from large areas of the body without producing any long term skin damage.

Understanding the cycle of hair growth and the structure of the follicle is one step in determining how permanent hair removal could be achieved. By locating the region of the hair which is responsible for initiating hair growth and devising a way of removing or destroying that area, a suitable mode of action might be established.

A simple model of a hair follicle, showing only the relevant features is illustrated in Figure 1 with the main characteristics of a fully formed hair shaft shown as they would be seen during the main growing phase. At the base of the follicle is a region known as the dermal papilla. It is from here that all hair growth occurs. The growth of a hair is cyclical, with three distinct phases known respectively as the anagen, catagen and telogen phases. The anagen phase is the first of these phases and occurs at a time when growth is initiated and lasts for a period of several weeks or even years depending on the location of the hair on the body. At the end of this period growth is suspended and the hair root becomes detached from the papilla. This phase is known as the catagen phase. From now on no more length is added to the hair but nevertheless it can remain held in the follicle for a period of several weeks if not months. This final phase of the cycle is known as the telogen phase. During the telogen phase the dermal papilla is dormant, but can be stimulated back into action prematurely by the mechanical removal of the hair from the follicle by, for example, brushing. Failing this the old hair would be naturally pushed out of the follicle at the beginning of the next growth cycle as a new hair is initiated in the anagen phase.

Two notable features of the structure shown in Figure 1 are the outer root sheath and the bulge. The outer root sheath is contiguous with the epidermis, and encloses a region of cells known as the bulge. Experiments investigating the potential for regrowth after removal of different sections of the hair follicle have indicated that if either the dermal papilla or the cells of the bulge are left intact

there will be some or complete regrowth of the hair. The reason for this is thought to be that the bulge contains stem cells for the growth of the dermal papilla so that, even if the papilla is completely removed or destroyed, a full recovery can be made by the recolonisation of the dermal papilla by these stem cells. It follows therefore that for a depilation technique to be successful both of these regions must be eradicated.

The use of lasers in depilation is a very embryonic field and will be discussed in more detail below. Nevertheless, work carried out in the United Kingdom in collaboration with a leading London teaching hospital has shown conclusively that control of hair growth for up to 120 days can be achieved. However, these trials have been carried out using ruby lasers operating at 694nm which are large and expensive systems having a high component cost. Furthermore, the technique essentially consists of the application of a 5mm spot of laser light with an energy density of 5-20 J/cm^2, applied spot by spot over the whole area to be depilated. Consequently, the depilation process is comparatively slow.

A summary of the various prior art methods of depilation, including ruby laser treatment, is set out in Table 1.

Returning to a consideration of the hair structure of Figure 1 there is also shown, in addition to the features previously mentioned, the distribution of melanocytes and blood vessels. These pigmented structures are crucial to the absorption of visible radiation within the skin and underlying tissue, and are integral to the methodology of depilation by light irradiation.

As is well known, there are a range of chemicals

TABLE 1

Technology	Status	Period of Depilation	Side Effects	Cost	Operator Issues
Shaving	Well established	Very short, a maximum of 5 days and produces an increasingly "strong" growth of hair	Relatively pain free but danger of haemorrhage if not careful	Negligible	Home use
Plucking	Well established	Very short - 10 days maximum	Painful and time consuming. Small areas only	Negligible	Home use
Waxing	Well established	Short 10 to 12 days, but quick for large areas	Painful with risk of scarring. Long intervals between use	Approx. £30 per treatment	Home use- larger areas by trained personnel only
Electrolysis	Well established	Largely discredited 10 days	Painful, slow, risk of infection	Approx. £60 per 30 minutes of treatment	Trained personnel only
Ruby Laser Treatment	On the horizon	120 days obtained by UK group	Relatively pain free	Capital investment of up to £60,000	Highly trained personnel only

known as chromophores that contain particular chemical bonds, such as C-C bonds which result in the chemicals having characteristic colours. The colours of hair, skin and blood are determined by the presence of these chromophores and it is their density that determines the depth of the colour at any particular point. In general, skin and hair colour is governed by the presence of melanin while the red colour of blood is as a result of the presence of haemoglobin. As shown in Figures 2a and 2b the absorption spectra of these two substances is significantly different, with the absorption by melanin tending to decrease monotonically with increasing wavelength while the spectrum of haemoglobin is composed of many maxima and minima. By comparing these two absorption spectra it can be seen that at certain wavelengths there will be a significantly higher absorption by one type of chromophore compared to the other. For example, at 694nm the absorption by haemoglobin is at a minimum while that by melanin is relatively high, while the situation is reversed at 577nm.

The attenuation of laser radiation as it passes through tissue is dependent not only on absorption but also on scattering. Nevertheless it is the absorption of the radiation by melanin and haemoglobin that is of particular importance as it is the selective photothermolysis by melanin that is the basis of laser depilation. The attenuation of radiation due to the absorption by these two chromophores can be represented at one level by the equation:

$$I = I_o \, K \exp - \left(\alpha_{m_{\lambda_1}} + \alpha_{m_{\lambda_2}} \right) d$$

where d is the tissue depth;

$\alpha_m(\lambda)1$ is the absorption coefficient of melanin at wavelength 1;

$\alpha_m(\lambda)2$ is the absorption coefficient of haemoglobin at wavelength 2; and

K is a constant

The depth at which light is attenuated to 1/e of its original value is called the penetration depth, and it can easily be shown from the above equation that this is equal to $1/\alpha$. For radiation having a wavelength between approximately 550nm and 1500nm the absorption coefficient is highly dependent on the absorption coefficients of melanin and haemoglobin. Outside this range other chromophores begin to contribute significantly to the absorption process. For example, water at longer wavelengths and proteins at shorter ones. Nevertheless it can be deduced from this that for radiation wavelengths between these limits the penetration depth is determined predominantly by the absorption coefficients of melanin and haemoglobin. An important result of the variation in penetration depth with wavelength is that the amount of energy that can be deposited in the required region will have a reciprocal dependence. Therefore if it is desired that the greatest deposition of energy is at the surface then a shorter wavelength should it be used.

However it will be appreciated from Figure 1 that in reality the picture is more complicated than this, in that the chromophores are not uniformly spread throughout the skin and underlying tissue but essentially occur in layers and at the site of the follicle.

A further complication in determing the exposure levels required for treatment is produced by the need to include relaxation times. Relaxation times play an

important role because of the need to get enough heat into a particular area to induce sufficient damage to cause cell death without at the same time causing unnecessary damage to the surrounding areas which could lead to scarring. Energy must be deposited into the area fast enough to compensate for any losses by conduction but also at a rate slow enough so that excessively rapid rises in temperature, and therefore explosive tissue heating, is avoided.

Generally speaking there are three modes of laser - tissue interactions; photochemical, photothermal and photoionisation. The duration of the pulse, wavelength and output power of a laser will determine which of these interactions is dominant in any particular situation. Generally photothermal interactions are those in which the pulse length is around the same time or longer than the thermal relaxation time of the tissue, whereas photoionisation dominates when the pulse length is relatively short. The photothermal reactions can therefore be subdivided into two terms of interest, the radiant heat effect, which is the initial heating of the target tissue by the incident radiation, and the conductive heat effect which is the transfer of the radiant heat to the surrounding tissue. Optimum laser pulse lengths are determined partly by the relaxation times and partly by treatment time considerations.

Actual cell death is brought about by different effects depending on the laser tissue interaction chosen. Photothermal heating of the tissue produces denaturation of proteins and breakdown of the cells, whereas in the case of photoionisation free radicals are the major cause of cell damage.

It has previously been reported that a reduction in hair density has been seen after treatment to

tattoos using Q-switched Nd:YAG lasers at sub-microsecond pulse lengths and energy densities of 0.4-10.0 J/cm^2. The reduction was only of the order of a few tens of percent but the possibility of using lasers for this type of treatment was recognised. Although the mechanism that was thought to be taking place was not reported at the time, it is now understood that it was the absorption of the laser light and the subsequent production of free radicals and their deleterious effect on the cells of the hair follicle, which induced the hair loss.

In US-A-5,059,192 Nardo Zaias described a method of permanent hair depilation using a Q-switched ruby laser. The move to a 696nm laser was prompted by the recognition that the absorption spectrum of tissue has a minimum at this wavelength, and that therefore selective thermolysis of the melanocytes would produce better results using radiation of this wavelength. The choice of a Q-switched laser was made based on the premise that by keeping the pulse length less than the thermal relaxation time of the melanin, approximately 1 microsecond, the selective thermolysis process would be optimised. It was stated that the optimum dose was 8 J/cm^2, with variations being expected for different coloured hair and, in particular, a higher dose for darker hair due to the increased scattering.

Further experiments using ruby lasers having a pulse length of 270 microseconds have shown that darker hair experiences greater temperature rises than lighter hair. Power densities of between 28 J/cm^2 and 57 J/cm^2 were used on human subjects, with a decrease in hair growth evident after up to 2½ months.

Another method using carbon powder suspended in a solution of peach oil was disclosed by Nikolai Tankovich in US-A-5,226,907. According to the method

the carbon-peach oil solution is first applied to the skin of a patent. The 10-20nm particles then migrate down the hair follicle where they remain trapped while the surface residue is removed. Irradiating the region with laser light of a wavelength in the region of one of the absorption peaks of carbon, in this case 10.6 microns - the wavelength of a CO_2 laser, induces the carbon to heat up, damaging or killing the adjacent tissue. The results that have been claimed using this technique include permanent hair loss without apparent pain or damage to the surrounding tissue. A similar proposal involving the staining of the hair with a dye and the subsequent irradiation of the hair with a particular wavelength of light corresponding to an absorption peak of the dye and leading to photothermal effects is also described. The stated advantage of these two modes of operation is that less radiation is needed to produce the desired effect. However, the drawback is that an extra step is required in the treatment process, with the added inconvenience and potential for non-uniformity in the distribution of the absorbing substance.

It is understood that the key parameters necessary to bring about the death of cells using a photothermal interation involve maintaining those cells at a temperature of 70°C for approx. 1mSec. Accordingly it is an object of the present invention is to provide an inexpensive but effective laser depilation system based on diode-laser technology. The system could have much reduced a component cost and could hence expand the market very substantially indeed.

According to a first aspect of the present invention there is provided an apparatus for the

depilation of mammalian tissue comprising a continuous wave laser diode. Preferably the laser diode is capable of applying 5 to 20 J/cm^2 of laser energy to each region of the tissue to be depilated for a period of 500 to 1000μs.

According to another aspect of the present invention there is provided an apparatus for the depilation of mammalian tissue comprising a source of laser radiation adapted to irradiate a target area with continuous wave or quasi continuous wave laser radiation having a wavelength in the range from 600nm to 1100nm and an energy density in the target area of between 2 J/cm^2 and 25 J/cm^2 for a duration of between 200μs and 5000μs so as to thereby selectively fatally damage the sub-dermal biological material associated with hair growth.

Advantageously, the source of laser radiation may be a laser diode.

Advantageously, the laser radiation may have a wavelength in the range from 630nm to 1100nm. Preferably the laser radiation may have a wavelength in the range from 780nm to 860nm.

Advantageously means may be provided for adapting the spatial characteristics of the laser radiation so as to form a line of light with which to illuminate the target area.

Advantageously, the source of laser radiation may emit quasi continuous wave laser radiation at a sufficiently high frequency to simulate continuous wave absorption in the target area. Preferably the source of laser radiation may be operated at a frequency such that the thermal relaxation time of the tissue in the target area is longer than an individual pulse cycle duration such that the resulting thermal experience is the same as that of a continuous

illumination of equivalent energy. Preferably the source of laser radiation may be operated at a frequency falling within the range from 10Hz to 10kHz and most preferably at a frequency of approximately 1kHz.

Advantageously means may be provided for directing a beam of the laser radiation at a portion of the target so as to form an illuminated area and means for scanning the beam of laser radiation so that the illuminated area moves across the target area until all of the target area has been illuminated. Preferably the scanning means may be adapted to scan the beam of laser radiation at a constant speed. Alternatively, the scanning means may be adapted to scan the beam of laser radiation across the target area with an increasing speed between successive portions of the target area. In yet another arrangement the scanning means may be adapted to scan the beam of laser radiation across the target area at varying speeds so as to maximise the ratio of the exposure time of individual portions of the target area to the time taken to scan the beam between successive portions of the target area. In yet another arrangement the scanning means may be adapted to scan the beam of laser radiation across the target area to selectively illuminate individual portions of the target in a predetermined sequence so as to minimise unwanted thermal damage.

Advantageously, the scanning means may comprise one or more galvanometric scanners and/or deflecting media. The deflecting media may include one or more mirrors or one or more acousto-optical scanners.

Advantageously means may be provided for varying the energy delivery of the laser radiation by modulating the output of the source of laser radiation

external to the laser cavity thereby regulating the time of illumination of each individual portion of the target area. Alternatively, means may be provided for varying the energy delivery of the laser radiation by modulating the output of the source of laser radiation by varying input power to the laser cavity without the loss of continuous stimulated emission.

According to a further aspect of the present invention there is provided a method of depilating mammalian tissue by the application of scanned CW laser diode light energy sufficient to cause retardation of hair growth.

According to yet a further aspect of the present invention there is provided a method for the depilation of mammalian tissue comprising the steps of providing a source of laser radiation, directing the laser radiation at a target area, and illuminating the target area with continuous wave or quasi continuous wave laser radiation having a wavelength in the range from 600nm to 1100nm and an energy density in the target area of between 2 J/cm^2 and 25 J/cm^2 for a duration of between 200μs and 5000μs so as to thereby selectively fatally damage the sub-dermal biological material associated with hair growth.

Advantageously, the source of laser radiation may comprise a laser diode.

Advantageously the laser radiation may have a wavelength in the range from 630nm to 1100nm. Preferably the laser radiation may have a wavelength in the range from 780nm to 860nm.

Advantageously the step of illuminating the target area may include adapting the spatial characteristics of the laser radiation so as to form a line of light on the target area.

Advantageously the source of laser radiation may

emit quasi continuous wave laser radiation at a sufficiently high frequency to simulate continuous wave absorption in the target area. Preferably the source of laser radiation is operated at a frequency such that the thermal relaxation time of the tissue in the target area is longer than an individual pulse cycle duration such that the resulting thermal experience is the same as that of a continuous illumination of equivalent energy. Preferably the source of laser radiation is operated at a frequency falling within the range from 10Hz to 10kHz and most preferably at a frequency of approximately 1kHz.

Advantageously the target area may be illuminated by directing a beam of the laser radiation at a portion of the target so as to form an illuminated area and scanning the beam of laser radiation so that the illuminated area moves across the target area until all of the target area has been illuminated. Preferably the beam of laser radiation may be scanned at a constant speed. Alternatively, the beam of laser radiation may be scanned across the target area with an increasing speed between successive portions of the target area. In another arrangement the beam of laser radiation may be scanned across the target area at varying speeds so as to maximise the ratio of the exposure time of individual portions of the target area to the time taken to scan the beam between successive portions of the target area. In yet another arrangement the beam of laser radiation may be scanned across the target area to selectively illuminate individual portions of the target in a predetermined sequence so as to minimise unwanted thermal damage.

Advantageously the beam of laser radiation may be scanned using one or more galvanometric scanners

and/or deflecting media. The deflecting media may comprise one or more mirrors or one or more acousto-optical scanners.

Advantageously the energy delivery may be varied by modulating the output of the source of laser radiation external to the laser cavity thereby regulating the time of illumination of each individual portion of the target area. Alternatively the energy delivered may be varied by modulating the output of the source of laser radiation by varying the input power to the laser cavity without the loss of continuous stimulated emission.

It can be shown that depilation is best achieved by illumination of the skin with light of an appropriate wavelength at a pulse duration of 400 to 1000μs and an energy density of 10 to 20 J/cm^2.

The laser technology currently available will produce such output parameters at a rate of 1Hz ie at one pulse per second. This means that the laser will produce of the order of 4 Joules per second. However, the pulse will only cover a circular area of, say, 5mm in diameter.

If one assumes that the diode laser used is 60W CW, then by definition it produces 60 Joules of energy every second. This is far greater than the energy produced by established technology. However, the diode laser will not produce the peak powers that the ruby technology generates. This limitation poses a dilemma which can be overcome by applying the following theory.

Energy Density Required	15 J/cm^2
Diode-laser power	60W
Diode laser energy	60J delivered every second

Exposure time required 1000μs

$$\text{Diode laser energy delivered in } 1000\mu s = \frac{60}{1000} = 60\text{mJ}$$

To achieve the desired energy density of 15 J/cm^2 the spot size would be:

$$\text{Energy Density} = \frac{\text{Applied Energy}}{\text{Area}}$$

$$\text{Area} = \frac{\text{Applied Energy}}{\text{Energy Density}} = \frac{60 \text{ X } 10^{-3}}{15}$$

$$\text{Area} = 4 \times 10^{-3}\text{cm}^2$$

Assuming that the diode can operate at 1kHz, then the area that can be covered in one second is:
Area of tissue depleted per second = $4x10^{-3}x10^{3}$ = 4cm^2

The area covered by the competing technology is:

$$\text{Area} = \pi \times (2.5 \times 10^{-1})^2 = 0.196 \text{ cm}^2$$

Thus the proposed technology would depilate 20 times faster than the established technology.

Using this theory, one currently preferred embodiment of the present invention involves controlling a continuous wave or quasi CW laser source to provide sufficient energy to mammalian tissue to selectively and fatally damage the sub-dermal biological material associated with hair growth. The laser output is directed by a scanning system capable of covering an area of approximately 300mm^2. The beam itself having an area of approximately 4 x 10^{-3}cm^2. The scanning system directs the beam from point to point illuminating an area equal to that of the cross-sectional area of the beam at the target for a given

time so as to deliver sufficient energy to permanently suppress hair growth.

The embodiment is shown schematically in Figure 3 to comprise a CW or quasi CW laser source 1 powered by a laser power supply 4. The laser source 1 emits a laser beam 3 to a scanning system 2 which then redirects the laser beam 7 so as to illuminate a portion of a target area 6 of mammalian tissue 5.

The energy delivered to each portion of the target having an area equal to the size of the beam, is controlled by the power of the laser and the time of exposure for that individual portion. Typically an energy density of 15 J/cm^2 is required to create the depilation effect. Using a CW laser output of power 60W, a spot size of 4 x 10^{-3} cm^2 and an exposure time of 1000μs (ie approximately equal to the thermal relaxation time for tissue) 60 mJ of energy will be delivered to that portion of the target.

Since the laser output is continuous, adjacent portions of the target may be illuminated successively as shown in Figure 4 by scanning the beam 7 in the direction of arrow 8 until the entire target area has been illuminated.

One advantage of this method is that a larger area of tissue can be treated in a given time period when compared to pulsed laser depilation systems. Even though the spot size of a pulsed laser is generally larger than that of the embodiment described, the pulsed laser systems suffer from the disadvantage that they are only capable of delivering a single pulse of energy at a low duty cycle, for example, 1Hz. Overall, this results in a slower treatment time. By using a continuous wave output and combining that with a means of accurately directing the laser beam, a simulated higher frequency of

operation results and the desired reduction of treatment time is achieved.

Other embodiments may make use of higher power laser systems to increase laser spot size whilst maintaining energy density thereby further reducing treatment time.

CLAIMS:

1. An apparatus for the depilation of mammalian tissue comprising a source of laser radiation adapted to irradiate a target area with continuous wave or quasi continuous wave laser radiation having a wavelength in the range from 600nm to 1100nm and an energy density in the target area of between 2 J/cm^2 and 25 J/cm^2 for a duration of between 200μs and 5000μs so as to thereby selectively fatally damage the sub-dermal biological material associated with hair growth.

2. An apparatus in accordance with claim 1, wherein the source of laser radiation is a laser diode.

3. An apparatus in accordance with claim 1 or claim 2, wherein the laser radiation has a wavelength in the range from 630nm to 1100nm.

4. An apparatus in accordance with any preceding claim, wherein the laser radiation has a wavelength in the range from 780nm to 860nm.

5. An apparatus in accordance with any preceding claim and including means for adapting the spatial characteristics of the laser radiation so as to form a line of light.

6. An apparatus in accordance with any preceding claim, wherein the source of laser radiation emits quasi continuous wave laser radiation at a sufficiently high frequency to simulate continuous wave absorption in the target area.

7. An apparatus in accordance with claim 6, wherein the source of laser radiation is operated at a frequency such that the thermal relaxation time of the tissue in the target area is longer than an individual pulse cycle duration such that the resulting thermal experience is the same as that of a continuous illumination of equivalent energy.

8. An apparatus in accordance with any preceding claim and including means for directing a beam of the laser radiation at a portion of the target so as to form an illuminated area and means for scanning the beam of laser radiation so that the illuminated area moves across the target area until all of the target area has been illuminated.

9. An apparatus in accordance with claim 8, wherein the scanning means is adapted to scan the beam of laser radiation at a constant speed.

10. An apparatus in accordance with claim 8, wherein the scanning means is adapted to scan the beam of laser radiation across the target area with an increasing speed between successive portions of the target area.

11. An apparatus in accordance with claim 8, wherein the scanning means is adapted to scan the beam of laser radiation across the target area at varying speeds so as to maximise the ratio of the exposure time of individual portions of the target area to the time taken to scan the beam between successive portions of the target area.

12. An apparatus in accordance with claim 8, wherein

the scanning means is adapted to scan the beam of laser radiation across the target area to selectively illuminate individual portions of the target in a predetermined sequence so as to minimise unwanted thermal damage.

13. An apparatus in accordance with any of claims 8 to 12, wherein the scanning means comprises one or more galvanometric scanners and/or deflecting media.

14. An apparatus in accordance with any preceding claim, wherein means are provided for varying the energy delivery of the laser radiation by modulating the output of the source of laser radiation external to the laser cavity thereby regulating the time of illumination of each individual portion of the target area.

15. An apparatus in accordance with any of claims 1 to 13, wherein means are provided for varying the energy delivery of the laser radiation by modulating the output of the source of laser radiation by varying the input power to the laser cavity without the loss of continuous stimulated emission.

16. A method for the depilation of mammalian tissue comprising the steps of providing a source of laser radiation, directing the laser radiation at a target area, and illuminating the target area with continuous wave or quasi continuous wave laser radiation having a wavelength in the range from 600nm to 1100nm and an energy density in the target area of between 2 J/cm^2 and 25 J/cm^2 for a duration of between 200μs and 5000μs so as to thereby selectively fatally damage the sub-dermal biological material associated with hair

growth.

17. A method in accordance with claim 16, wherein the source of laser radiation is a laser diode.

18. A method in accordance with claim 16 or claim 17, wherein the laser radiation has a wavelength in the range from 630nm to 1100nm.

19. A method in accordance with any of claims 16 to 18, wherein the laser radiation has a wavelength in the range from 780nm to 860nm.

20. A method in accordance with any of claims 16 to 19, wherein the step of illuminating the target area includes adapting the spatial characteristics of the laser radiation so as to form a line of light.

21. A method in accordance with any of claims 16 to 20, wherein the source of laser radiation emits quasi continuous wave laser radiation at a sufficiently high frequency to simulate continuous wave absorption in the target area.

22. A method in accordance with claim 21, wherein the source of laser radiation is operated at a frequency such that the thermal relaxation time of the tissue in the target area is longer than an individual pulse cycle duration such that the resulting thermal experience is the same as that of a continuous illumination of equivalent energy.

23. A method in accordance with any of claims 16 to 22, wherein the target area is illuminated by directing a beam of the laser radiation at a portion

of the target so as to form an illuminated area and scanning the beam of laser radiation so that the illuminated area moves across the target area until all of the target area has been illuminated.

24. A method in accordance with claim 23, wherein the beam of laser radiation is scanned at a constant speed.

25. A method in accordance with claim 23, wherein the beam of laser radiation is scanned across the target area with an increasing speed between successive portions of the target area.

26. A method in accordance with claim 23, wherein the beam of laser radiation is scanned across the target area at varying speeds so as to maximise the ratio of the exposure time of individual portions of the target area to the time taken to scan the beam between successive portions of the target area.

27. A method in accordance with claim 23, wherein the beam of laser radiation is scanned across the target area to selectively illuminate individual portions of the target in a predetermined sequence so as to minimise unwanted thermal damage.

28. A method in accordance with any of claims 23 to 27, wherein the beam of laser radiation is scanned using one or more galvanometric scanners and/or deflecting media.

29. A method in accordance with any of claims 16 to 28, wherein the energy delivery is varied by modulating the output of the source of laser radiation

external to the laser cavity thereby regulating the time of illumination of each individual portion of the target area.

30. A method in accordance with any of claims 16 to 28, wherein the energy delivered is varied by modulating the output of the source of laser radiation by varying the input power to the laser cavity without the loss of continuous stimulated emission.

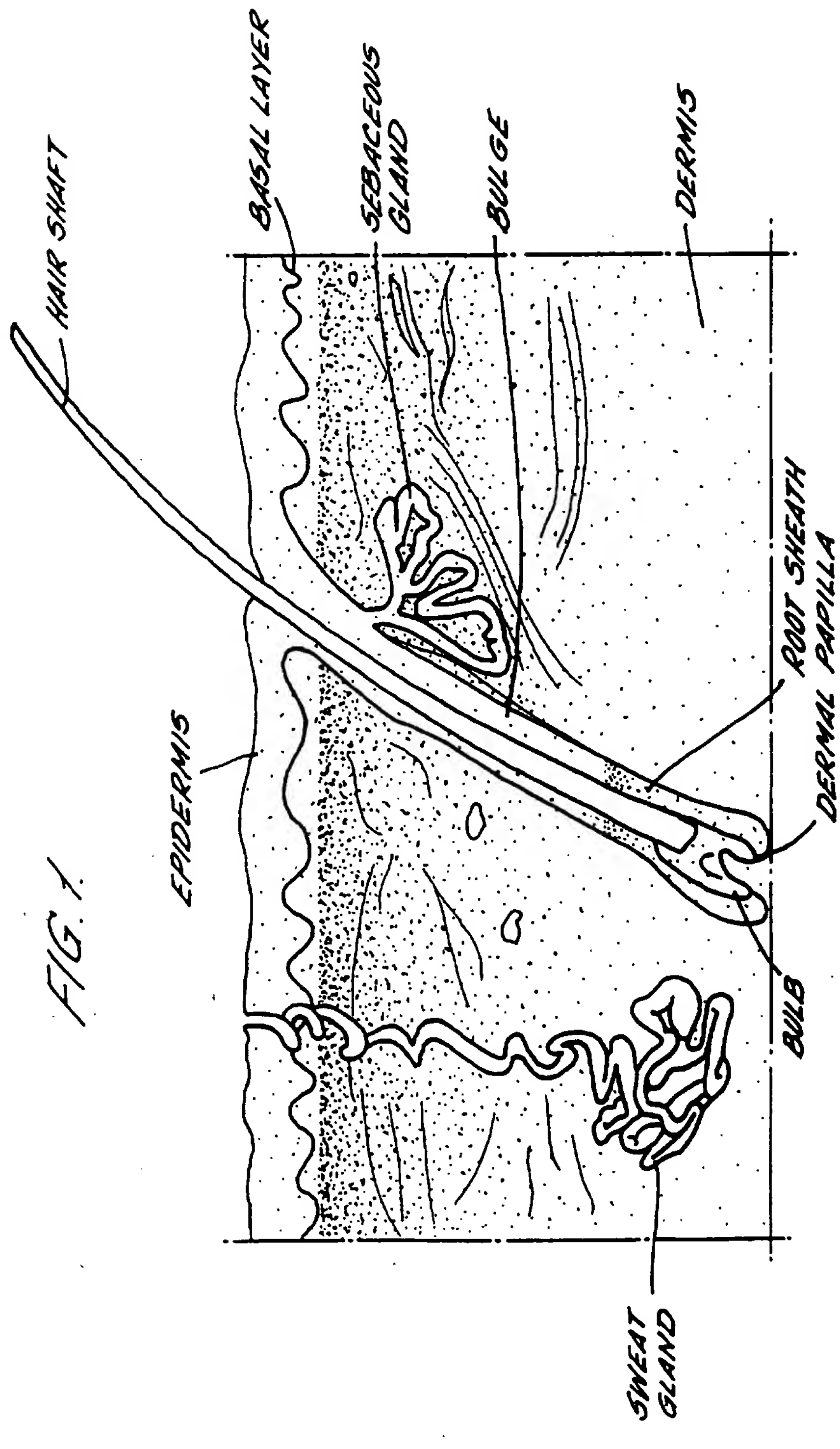
HAIR SHAFT
BASAL LAYER
SEBACEOUS GLAND
BULGE
DERMIS
EPIDERMIS
ROOT SHEATH
DERMAL PAPILLA
BULB
SWEAT GLAND

FIG. 1

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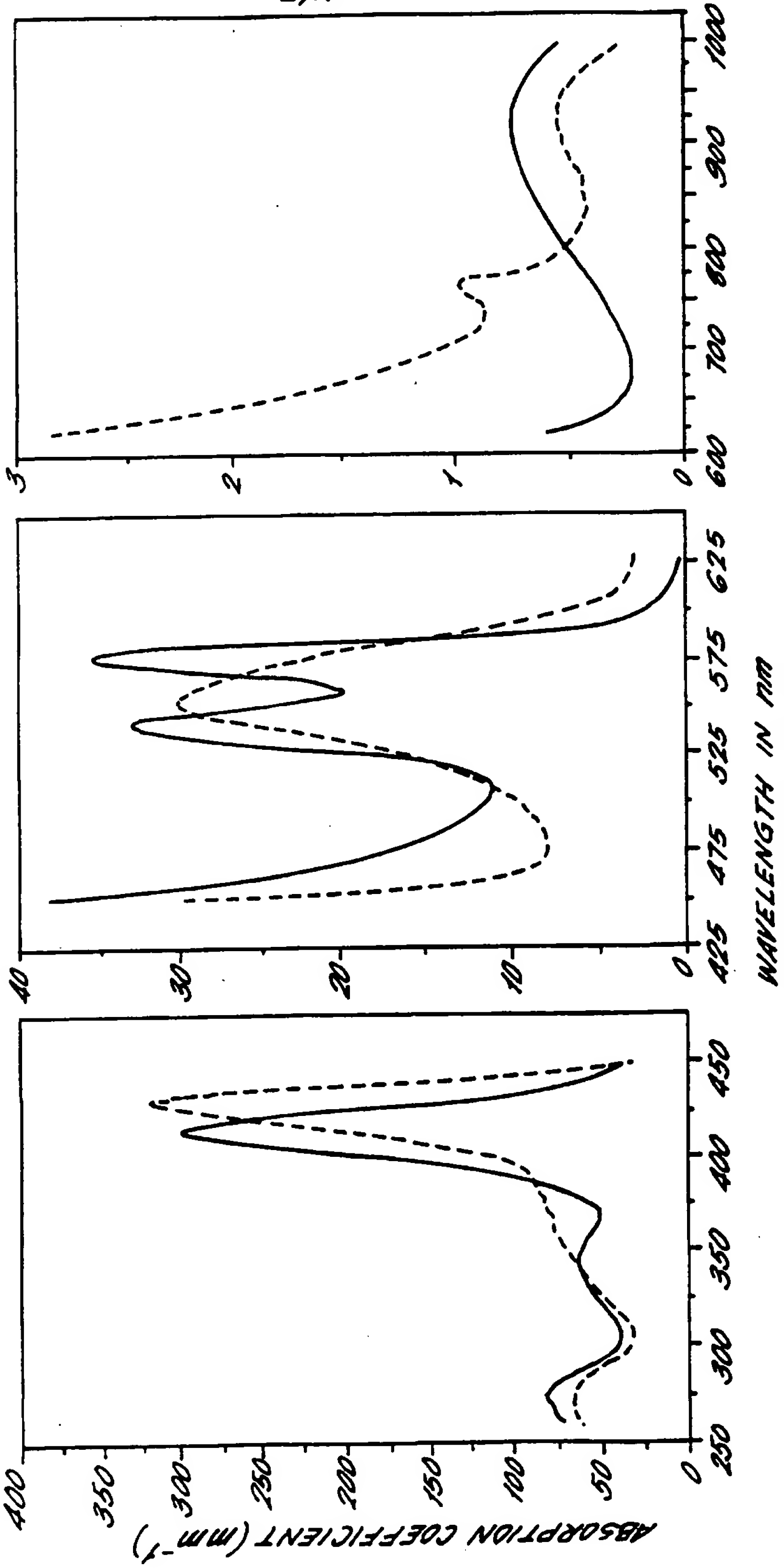
FIG. 2a.



ABSORPTION SPECTRUM OF HAEMOGLOBIN (SOLID) AND OXYHAEMOGLOBIN (DASHED)

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FIG. 2b.

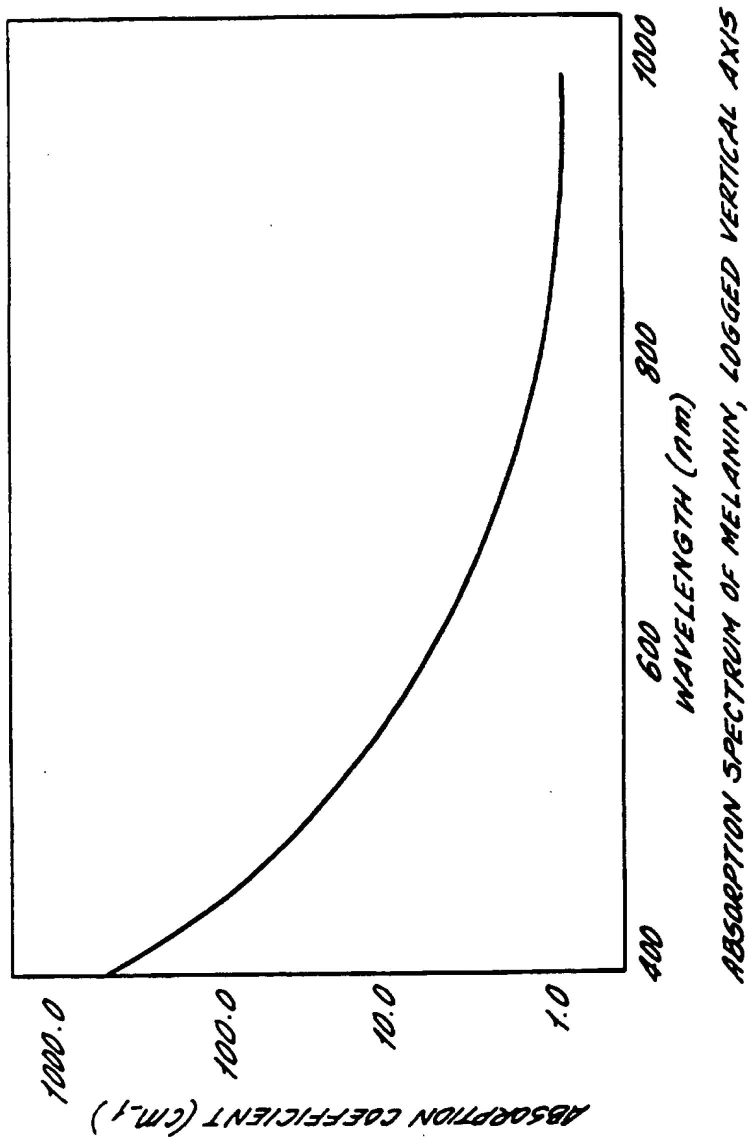

1000.0
100.0
10.0
1.0
ABSORPTION COEFFICIENT (CM-1)
400
600
800
1000
WAVELENGTH (nm)
ABSORPTION SPECTRUM OF MELANIN, LOGGED VERTICAL AXIS

FIG. 3.

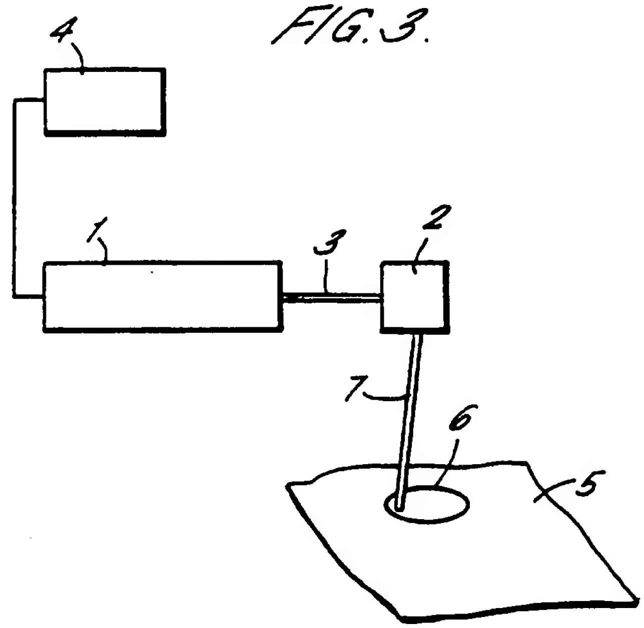
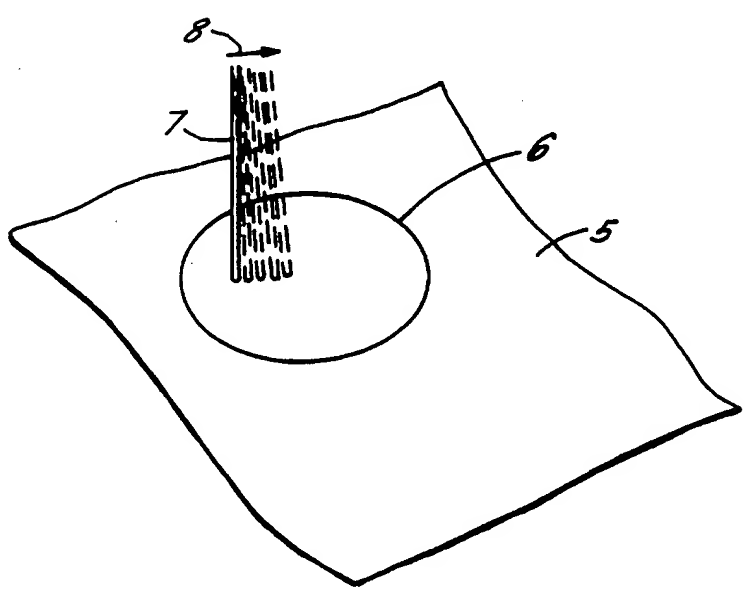


FIG. 4.



INTERNATIONAL SEARCH REPORT

Inter. ...al Application No
PCT/GB 97/00354

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 A61B17/41 A61B17/36 A61N5/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 A61B A61N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 93 21993 A (SEGAL) 11 November 1993 see page 10, line 30 - page 11, line 9 see page 14, line 3 - line 10 see page 14, line 16 - line 30 see page 16, line 8 - line 19 see page 18, line 23 - page 19, line 9 ---	1-30
X	FR 2 571 264 A (NAVARRO) 11 April 1986 see page 1, line 3 - line 5 see page 2, line 1 - line 29 ---	1-30
X	DE 38 37 248 A (TEICHMANN) 3 May 1990 see column 2, line 51 - column 3, line 19 see column 4, line 25 - line 38 ---	1,8-16, 23-30
X	US 3 916 143 A (FARRELL) 28 October 1975 see column 1, line 33 - line 43 ---	1,16
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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"&" document member of the same patent family

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Date of the actual completion of the international search	Date of mailing of the international search report
6 June 1997	13. 06. 97

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+ 31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+ 31-70) 340-3016	Moers, R

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INTERNATIONAL SEARCH REPORT

Inten   al Application No
PCT/GB 97/00354

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 973 848 A (KOLOBANOV ET AL.) 27 November 1990 see column 1, line 55 - column 2, line 33 see column 16, line 33 - line 41 see column 10, line 18 - column 11, line 49 ---	8-15, 23-30
A	WO 95 15725 A (CLEMENT) 15 June 1995 see abstract ---	1,16
A	WO 84 02644 A (WEISSMAN) 19 July 1984 see abstract; figures 1,2 ---	1,8,16, 23
A	US 5 059 192 A (ZAIAS) 22 October 1991 cited in the application see column 3, line 23 - line 56 -----	1,16

1

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

Intern. al Application No
PCT/GB 97/00354

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9321993 A	11-11-93	AU 4228593 A	29-11-93
FR 2571264 A	11-04-86	NONE	
DE 3837248 A	03-05-90	NONE	
US 3916143 A	28-10-75	NONE	
US 4973848 A	27-11-90	NONE	
WO 9515725 A	15-06-95	AU 1195595 A	27-06-95
		BG 100703 A	28-02-97
		BR 9408266 A	10-12-96
		CA 2178631 A	15-06-95
		CN 1137231 A	04-12-96
		CZ 9601685 A	13-11-96
		EP 0732895 A	25-09-96
		FI 962359 A	07-06-96
		NO 962354 A	09-07-96
		NZ 277065 A	26-05-97
		PL 314912 A	30-09-96
WO 8402644 A	19-07-84	EP 0134206 A	20-03-85
US 5059192 A	22-10-91	NONE	